TAPCO a division of Thompson Ramo Wooldridge Inc.

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C.A. Thompson Ramo Wooldridge, Inc., Cleveland, Ohio Tapco Div.

Carole — do you file this or do I? EMC

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MONTHLY PROGRESS REPORT

No. 6 [Development of an "Osmotic still" ...]

~~for~~

December, 1962

Submitted by 0 auth. 15 Jan. 1963 21 p refs

(NASA CR-55697) OTS:

NASA contract NAS 3-2551

NEW PRODUCT RESEARCH of TAPCO

OTS PRICE

XEROX $ 2.60 ph

MICROFILM $ 0.83 mf

Monthly Progress Report No. 6

January 15, 1963

I INTRODUCTION

This document represents the sixth monthly report covering the work on the experimental program for development of an "Osmotic Still" and improvements in the performance characteristics of the Ionics Dual Membrane Fuel Cell during the month of December 1962. This development work is being accomplished under NASA-Lewis Research Center Contract No. NAS 3-2551 by the New Product Research Department of TAPCO and ~~Ionics, Inc. as a subcontractor to TAPCO.~~ NASA

II OVERALL PROGRESS

A. Tapco Portion of Program

1. A total of five (5) successful tests were completed with the American Machine and Foundry A-60 Anion membranes. These tests were initiated by drying the membranes prior to installation in the laboratory test model still. This drying procedure prevented the initial membrane "sweating" described in Monthly Progress Report No. 5. During these tests, the membrane temperatures ranged from 175°F to 200°F and the Ph of the condensate was from 4 to 5. However, water extraction rates were extremely small (approximately 8 cc/hr ft^2 at best).

2. The Monel metal support screens showed extreme corrosion early in the course of the above tests and were recoated with Teflon, utilizing a 20 percent dispersion to produce a heavier protective coating. This heavier coating, however, was also found to be unsatisfactory as continued corrosion resulted.

3. Investigation of Kel-F non-wetting protective coatings was pursued and Kel-F dispersion material has been received for testing.

4. After repeated failure of the acid vane type pump in the test rig, a parastaltic type pump was installed. Initial tests with hypalon tubing in this pump indicate that it will be satisfactory for future tests.

B. Ionics Portion of Program

1. Task III has not progressed as rapidly as expected and costs are running higher than originally planned. Revision of plans for the remainder of the contract are such as to complete the work on time and within cost, however.

2. A subcontract was written with Arthur D. Little, Inc. to evaluate all metallic and plastic materials that might be resistant to contact with 6N H_2SO_4 at 95°C. This subcontract

B. Ionics Portion of Program Cont'd

also covers work on reducing the electrode-membrane resistance. Preliminary investigations show this is an area which may contribute substantially to improving performance. Work to date on this subcontract indicates the possibility of satisfactory resistance of Kel-F, Silicone rubber, and goldplated copper. The tests are still in process however.

3. Clevite Corporation in Cleveland has undertaken manufacture of sample sintered electrodes in an effort to improve uniformity by die pressing. Electrodes have been made but have not as yet been received.

4. The construction of the testing equipment and instrumentation has been essentially completed, and screening tests on single cells can now proceed. A new acid accumulator was designed and 12 accumulators constructed and installed on the equipment. The previous acid accumulator was a constant source of acid leakage.

5. In addition to the eight cells reported on in December, six new cells have been subjected to initial screening tests at 60°C to evaluate paste electrodes and a new Kel-F sintered electrode as well as a new "tight" membrane. Initial performance was disappointing, due, we believe, to liquid accumulation in the gas compartments. This, we believe, is due to direction of gas flow. Further analysis will be conducted. One cell operated satisfactorily for 1344 hours before test discontinuation.

6. Principal materials for construction of subsequent test cells are now on hand with the exception of the test membranes and test electrodes under development.

III CURRENT PROBLEMS

A. Tapco Portion of Program

1. Although successful tests with the AMF Anion membranes were obtained, low Ph water (Ph 1 and 2) is obtained upon initial startup after overnight shutdown. (See test data.) This Ph rises to 4 to 5 after a so-called "cleaning-up" period of from 2 to 4 hours. Additional investigations to reduce or eliminate this start-up phenomena is necessary. Apparently the membrane drying procedures followed aid the eventual clearing up of the "sweating" phenomena but does not completely eliminate its occurence during the initial period of test.

2. Failure of the Teflon coating to protect the Monel metal support screens requires investigation of other protective coatings. The Kel-F coating material appears promising as a moisture proofing agent and its use is being pursued.

A. Tapco Portion of Program Cont'd

3. The acid vane type pump failures to date have been mechanical in nature. The substitution of a parastaltic type pump in the test rig has solved this problem.

B. Ionics Portion of Program

1. As reported last month, production of uniform, sintered electrodes remains a current problem. Three approaches are being pursued to resolve this: Clevite Corporation of Cleveland is experimenting with sample electrodes pressed and sintered in a die; Arthur D. Little, Inc. is experimenting with application of the electrode to the membrane; Ionics is experimenting with modifications of the electrode paste utilizing Kel-F which will allow manufacture of electrodes at lower pressures and temperatures.

2. Liquid in the gas compartments has been experienced particularly in the tests at 60°C. The cause of this liquid transfer from the electrolyte compartment is being investigated. Membranes have been rechecked for leakage, and this does not appear to be the cause. Pressure tests on the cells prior to screening tests indicate no internal cross leaking. Different membranes will be tested in an effort to eliminate this problem.

3. Corrosion remains a problem at elevated temperatures. In addition to the work at Ionics, a professional corrosion expert at Arthur D. Little, Inc. is working on the solution of this problem. Preliminary fuel cell design changes have been discussed which might eliminate the need for metallic parts other than the platinum electrode.

IV NEXT MONTH'S EFFORT

A. Tapco Portion of Program

1. Establish Kel-F coating techniques to eliminate or reduce corrosion of the Monel metal support screens.

2. Initiate performance tests of the AMF Cation membranes C-60 and C-103.

3. Procurement and test of a third manufacturer's membranes.

B. Ionics Portion of Program

1. Tests to establish the present characteristics of the original dual membrane fuel cell will be completed during January. These results will serve as the basis for improvement under this contract. Tests will be run at 30°C and 60°C.

2. Material testing work at Arthur D. Little, Inc. will be completed during the next month. Suitable materials for organic and metallic components of the fuel cell should be selected.

B. Ionics Portion of Program Cont'd

3. Initial sample screening tests on 2" x 2" electrodes from Clevite should be completed; and if a satisfactory electrode can be made by the Clevite process, 2" x 18" electrodes will be ordered and subjected to test. The 2" x 2" size is being used since Clevite agreed to prepare such sample electrodes for us at a modest cost.

4. Screening tests will be run on membranes with substantially lower porosity (10 to 15 angstroms) than the standard membranes in an effort to reduce liquid transfer.

5. Initial design studies will be made to determine best configuration of five-cell battery. Sample batteries will be constructed.

V TEST RESULTS

A. Tapco Portion of Program

1. Initial performance tests on the AMF A-60 Anion membrane utilized the same membranes used in the preliminary tests which were described in Monthly Progress Report No. 5. The nominal test conditions were 30% H_2SO_4 at 175°F with a condensing temperature of 160°F. A water extraction rate of 1.18 cc/hr ft^2 was obtained with a Ph of 4 to 5 as determined with Ph litmus paper.

2. The test conditions for the second test on these membranes were 30% H_2SO_4 at 175°F with a condensing temperature of 155°F. A water extraction rate of 3.2 cc/hr ft^2 was obtained with a Ph of 4 to 5. The failure of a stopcock at the condenser outlet terminated this test.

3. Early membrane rupture prevented a third performance test on these membranes. Disassembly of the still showed that the membrane failure was due to a puncture caused by the edge of the support screen. The gasket had extruded under repeated bolt tightening to maintain a torque of 50 in-lbs and had pinched the membrane between the screen edge and the rubber gasket. Also, the Teflon coating had flaked off the screen in some areas and the Monel metal screen was severely corroded.

4. The Monel screens were cleaned in a solution of 20% chromium trioxide, 10% sulfuric acid and 70% water. They were then coated with a 20% Teflon dispersion and sintered at 700°F for 30 seconds.

5. New A-60 Anion membranes were installed in the test unit with the freshly coated support screens. A new gasketing and support spacing arrangement was used to prevent puncturing with the screen edge.

A. Tapco Portion of Program Cont'd

6. The nominal conditions for the first test on the newly installed A-60 membranes were 30% H_2SO_4 at 175°F with a condensing temperature of 140°F. A water extraction rate of 6.1 cc/hr ft^2 was obtained with a Ph of 4.

7. The nominal conditions for the second test on these membranes were 30% H_2SO_4 at 175°F with a condensing temperature of 120°F. A water extraction rate of 8.0 cc/hr ft^2 was obtained with a Ph of 4-5. This test was terminated due to a leak in the separator seal between the magnets in the acid pump. Inspection of the pump revealed wear on the separator due to misalignment of the magnets.

8. The test conditions for the third test on these membranes were 30% H_2SO_4 at 200°F with a condensing temperature of 180°F. A water extraction rate of 3.0 cc/hr ft^2 was obtained with a Ph of 4-5. This test ended with the failure of the vacuum line between the still and the monometer. This line was accidentally overheated resulting in failure.

9. The fourth and final test attempted during this reporting period was not completed due to the acid, vane type pump failure which occurred just as equilibrium was reached at a 200°F acid temperature. A Ph of 1.0 was obtained continuously during heatup. Upon disassembly of the test unit, it was found that the vapor side of both of the membranes was wet at points of contact with corroded areas of the support screen. The corrosion of the screen was evidenced by large areas of green crystal clusters.

B. Ionics Portion of Program

1. Since the bulk of the effort for this reporting period was devoted to modification and final check-out of the test apparatus, only limited screening tests were conducted. These are reported in the attached Table 1 and discussed below. The numbering system used for identifying these cells corresponds to the laboratory notebook page number covering the construction of the cell.

As indicated in last month's report, small membrane cracks have lead to cell failures. Cell D9723, which was reported as still running in the report for November, failed to operate satisfactorily after 1344 hours due to excessive liquid in the gas chambers. The output voltage remained greater than 0.6 volt for more than 1000 hours. Examination of the disassembled cell showed small holes in the membranes.

To overcome the cell failure described as "membrane drying," it was thought reasonable to vibrate the cell after filling to free

TABLE I

SINGLE CELL SCREENING TESTS

Cell #	Type of Electrode	TEMP., °C	Pressure, Psig Electrolyte	Gas	Current Amperes	Average Voltage	Time of Data Reading (Hrs.)	Remarks
D9723	Sintered	30	20	15	4.0	0.76	20	Test discontinued Blockage of H_2 and O_2 inlets. Liquid in gas compartments. Membranes showed small holes. Electolyte-gas pressure differential maintained to assure adequate membrane-electrode contact.
						0.74	108	
						0.72	252	
						0.71	348	
						0.72	396	
						0.64	564+	
						0.64	624	
						0.71	720	
						0.65	936	
						0.64	960	
						0.58	1104	
					4.5	0.52	1128	
					4.0	0.59	1176	
						0.59	1344	
D9739	Paste	60°C	20	15	4.0	0.56	1	Discontinued. Water bath failure after 12 hours of satisfactory cell performance.
D9740	Paste	60°C	20	15	4.0	0.82	1	Discontinued. Water bath failure same as for D9739
D9743	Sintered	60°C	20	15	2.0	0.10	6	Discontinued for evaluation. Excess liquid in gas compartments.
					2.0	0.48	78	
					2.0	0.10	102	
						0.24	192	
D9744	Sintered	60°C	20	14	4.0	0.62	6	"Tight" membrane. Test discontinued, for evaluation of voltage drop.
						0.74	96	
						0.62	120	
						0.23	192	
D9745	Sintered	60°C	20	15	4.0	0.745	48	"Tight" membrane. Discontinued for evaluation
					4.0	0.310	120	
D9746	Sintered (Kel F)	60°C	20	15	4.0	0.112	120	Discontinued for evaluation.
					2.0	0.160	168	

B. Ionics Portion of Program Cont'd

the electrolyte of entrapped air and to feed the gases to the cells from the bottom of the gas chamber rather than from the top. This avoids directing the streams of dry gas on the membrane opposite the most likely spot for a bubble of gas to collect in the electrolyte compartment. However, in the four cells operating in this manner, D9743, D9744, D9745, and D9746 operation has not been satisfactory. The customary values of voltage and current, i.e., 0.6 to 0.8 volt at four amperes, can be obtained only after extensive purging and can be maintained for only a few hours. Consequently, the cells will be run in the former manner to evaluate accurately several promising variations, while the cause of the liquid accumulation will be analyzed. Cells D9739 and D9740, one of which showed promise as shown in the table, are to be rerun.

These results are not encouraging. However, the principal problem seems to be largely caused by liquid transfer. This same problem has been solved in other fuel cell work through proper selection of membranes, so it appears very likely that membrane evaluation during the next period plus reversal of the gas flow will alleviate this condition.

2. Material's testing to date is summarized in Table II. Since the principal corrosion problems show up at 60°C, testing has been confined to 60°C and 95°C. The results to date are:

1. Epoxy fiberglass which has been used as a spacer material gains weight and becomes brittle and whiter at both the test temperatures. Since this material will be in direct contact with the electrolyte, it appears a new spacer material must be found. Since Plaskon, a polymer of Chlorotrifluorethylene, seems to hold its weight and appearance very well at both the test temperatures, this material may serve as a satisfactory spacer material.

2. Kel-F, Teflon, and Trilok 6027-1-1 (73% polypropylene, 27% polyethylene) appear to resist sulfuric acid at 95°C reasonably well. Since resilient, resistant, highly porous filler material may be desirable in cell construction, these tests are encouraging.

3. Monel Alloy #400 does not lose much weight, but its surface deterioration may prohibit its use as a collector and pusher plate material. A thin coat of platinum or gold may overcome this difficulty since some success with gold plating has been experienced at 60°C.

4. A retest of the 8-oz. glass backed cation membranes showed a small gain in weight, and the sample became dark bronw. Since these results contradict earlier tests, the test will be re-run. Screening tests on single cells will determine the deleterious effect, if any, on the discoloration.

TABLE II

MATERIAL TESTING AT 60°C AND 90°C

Name of Material	Temperature = 60°C Test Time (Hours)	Temperature = 60°C Loss or Gain in Wt. (%)	Temperature = 60°C Visual Observations	Temperature = 95°C Test Time (Hours)	Temperature = 95°C Loss or Gain in Wt. (%)	Temperature = 95°C Visual Observations
Plaskon TVS-300	580	0.0	No change	580	0.0	No change
Kel F	580	0.0	No change	580	+6.5	No change
Trilok 6027-1-1	-	-	-	580	+6.5	Slight whitening of black fibres
Monel Alloy #400	530	-1.5	Surface became copper colored	550	-3.0	Blackening of surface
Epoxy	-	-	-	580	+15.0	Whitening of surface; material brittle
Membrane 8-oz. Glassbacked	-	-	-	580	+2.0	Surface became dark brown
Buna N	-	-	-	530	+20.6	Loss of elastic property; easy to tear
Gold-Plated Titanium Au = 400 microinches	650	-2.1	No change in appearance	-	-	-
Gold-Plated Titanium Au = 200 microinches	140	Completely Eaten	Gold flaked off	-	-	-
Gold-Plated Titanium Au = 300 microinches	-	Completely Eaten	Gold flaked off	50	All Titanium Eaten	Gold flaked off
Gold-Plated Titanium Au = 500 - 600 microinches	-	-	-	410	All Titanium Eaten	Gold flaked off

Where data or information is not indicated, either none is yet available or it has been previously reported.

5. Gold plated titanium having 400 microinches of gold withstood sulfuric acid at 60°C whereas samples plated with lesser amounts of gold were attacked. At 95°C, gold thicknesses up to 500-600 microinches failed to produce a hole-free surface on the titanium, emphasizing the inherent difficulty of plating titanium as well as its rapid attack by sulfuric acid. Following a presently planned review meeting with Arthur D. Little's people on January 16, further work on materials with little promise will be discontinued.

Initial work on materials at Arthur D. Little, Inc. has indicated that a polyester fiber-glass material and possibly a cast polyester may show satisfactory resistance to 6N H_2SO_4 at elevated temperatures. Also, silicone rubber is far more resistant than the Buna N gasketing material now being used. Copper, it has been determined, is attacked more slowly than titanium and is easier to plate, hence serves as a better base for metallic parts if a satisfactory protective coating can be applied. Copper strips plated with 250 microinches of gold are to be tested.

3. Initial attempts to form sintered electrodes in a confined die were unsuccessful due to die failure. A new die is being made. Control of thickness and porosity is the objective of this new technique. Porosity measurements will be attempted.

Incorporation of Kel-F in the electrode paste and elimination of magnesium oxide has led to a new and interesting electrode fabrication technique. Lower sintering pressures and temperatures than those used for the Teflon electrode have been possible. Magnesium oxide, formerly used to achieve porosity, has been eliminated since the lower sintering pressure results in a less dense electrode.

Attempts have been made by the Arthur D. Little, Inc. people to "blast" the platinum into the membrane. These have been unsuccessful, and the next effort will be to plate the catalyst electrolitically or chemically. A small test rig has been built to run quick screening tests on membranes and membrane-catalyst combinations to determine relative resistances.

VI QUALITY ASSURANCE

A. Tapco Portion of Program

Generally speaking, the Quality Assurance Status of the program is much the same as reported in December. The TRW portion of the program can be considered as being on schedule and progressing satisfactorily.

A. Tapco Portion of Program Cont'd

In a telephone conversation with R. McDonald, Quality Control Manager of Ionics, Inc., we were informed that he has completed his Quality Control Manual. It is their intention to have it ready for distribution during the week of January 14, 1963. The quality assurance survey at Ionics, Inc. scheduled for January 15, 1963 is to be postponed until March barring any emergency requiring immediate attention prior to that time. It is felt the quality assurance program at Ionics is progressing satisfactorily.

Dupont has been unable to supply us with the Pontamine Blue Dye that we intended to use to check the soundness of membrane material prior to use in the Osmotic Still because we could not furnish them with a specific catalog number. Apparently there are many different types and grades of dye known as Pontamine Blue.

Further attempts are to be made by our procurement people to obtain a dye(s) to be used on either cation and/or anion membranes for leakage tests. This method of testing still appears to be preferable to pressure testing.

B. Ionics Portion of Program

The specific quality assurance effort on the contract has been temporarily discontinued. In keeping with the original contract agreement, it will be reinstituted in Tasks 5 and 6. An active working system of quality control was established at the start of the program and is now in effect. Revised drawings of all elements of the present fuel cell have been made with complete specifications.

Ionics, as an in-house effort, has completely revised its entire quality control procedures to meet the requirements of NASA. Manuals for quality control are in draft form and should be available for use throughout the Company by the end of January.

TAPCO a division of
Thompson Ramo Wooldridge Inc.

FINANCIAL REPORT

For

DECEMBER - 1962

(Contract NAS 3-2551)

Submitted by

NEW PRODUCT RESEARCH OF TAPCO

(Attachment to Monthly Progress Report No. 6)

FINANCIAL REPORT

for

Contract NAS 3-2551

for

Period Ending December 31, 1962

	Current Month	Total To Date
TRW Engineering Hours	177.0	1132.5
TRW Costs and Commitments	\$2,770	\$18,581
Subcontractor Costs and Commitments	10,206	71,866
TOTAL	\$12,976	\$90,447

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T1 H2SO4 IN °F	T2 H2SO4 OUT °F	VACUM PRESS C.M	CIR. H2O °F	VAC. LINE °F	VAC. LINE MAN °F	FLOW C.M		
11:25	175.5	175.0	23.9	161.0	196	178	6.9		
11'37					Purged	from	23.7	To 24.2	
11:40	175.5	175.0	23.9	160.5	196	180	6.9		
11:52					PURGED	FROM	24.0	TO 24.2	
11:55	174.5	174.0	24.2	159.0	196	180	6.9		
12:07					PURGED	FROM	24.0	TO 24.2	
12:10	174.5	174.0	24.1	161.0	194	180	6.9		
12:22					PURGED	FROM	23.7	TO 24.2	
12:25	175.5	175.0	24.0	160.7	196	182	7.0		
12:39							23.7	TO 24.2	
12:41	174.6	174.0	24.1	161.0	196	182	7.0		
12 53	~~174.5~~				Purged	From	23.9	To 24.2	
12 55	174.5	174.0	23.8	160.7	197	183	7.0		
13:07					PURGED	FROM	23.5	TO 24.2	
13:10	175.8	175.0	23.7	161.0	197	184	7.0		
13:22					PURGED	FROM	23.6	TO 24.2	
13:25	175.5	175.0	23.8	160.0	198	186	7.0		
13:37					PURGED	FROM	23.6	TO 24.2	
13:40	176.0	174.5	23.9	160.0	199	187	7.0		
13:52					PURGED	FROM	23.9	TO 24.2	
13:55	174.5	174.0	24.0	161.0	199	187	7.0		
Start 14:07					PURGED	FROM	23.8	TO 24.2	
14:10	176.5	176.0	24.6	161.0	199	188	7.0		
	TEMP. DIFFICULTIES				CHANGE	COLLECTOR			
14:42					PURGE	FROM	23.2	TO 24.2	
14:45	176.0	175.5	23.7	161.0	199	189	7.0		
13:57					PURGE	FROM	23.9	TO 24.2	
15:00	174.0	173.0	24.1	161.0	199	189	7.0		
15:12					PURGED	FROM	23.6	TO 24.2	
15:15	176.0	175.5	23.7	161.0	199	189	7.0		

TITLE PERFORMANCE TEST #1

ANION-60 MEMBRANE AMF. MEMBRANE #IV

ELECTROLYTE TEMP 125°F VAP. PRESS. 23.9 C.M

FLUID H_2SO_4 CONC — 30%

ENGR. T.H.
J.K.

DATE 12-3-62

TEST NO. OSMATIC ST

PROJECT 512-029724

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Thompson Ramo Wooldridge Inc.

TIME	T1 H_2SO_4 IN °F	T2 H_2SO_4 OUT °F	VACUM PRES C.M	CIR. H_2O °F	VAC. LINE °F	VAC. LINE MAN. °F	FLOW C.M		
15:27					PURGE FROM 23.4 TO 24.2				
15:30	175.5	175.0	23.8	161.0	199	189	7.5		
15:42					PURGE FROM 23.4 TO 24.2				
15:45	175.0	174.0	24.0	161.0	199	189	6.9		
16:02					PURGE FROM 23.4 TO 24.2				
16:05	176.0	175.0	23.7	161.2	199	189	6.9		
16:17					PURGE FROM 23.4 TO 24.2				
16:20	176.0	175.0	23.7	160.7	199	189	6.9		
STOP 16:32					Purge From 23.4 To 24.2				
16:40	175.6	175.0	23.6	160.8	199	187	6.9		

Shut Down

PH = 4 - 5

Total Quantity From 1407 Hrs = 3.0 ml

TITLE PERFORMANCE TEST #1
BAROMETER READ. 29.32 TEMP. COMPENSATED
ANION-60 MEMBRANE AMF. MEMBRANE #12
ELECTROLYTE TEMP. 175°F VAP. PRES. 23.9 C.M
FLUID H_2SO_4 Conc = 30%

ENGR. TH
J.K.
DATE 12-3-62
TEST NO. OSMATIC STILL
PROJECT 512-029324

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TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T1 H_2SO_4 IN °F	T2 H_2SO_4 OUT °F	VACUM PRES. C.M	CIE. H_2O °F	VAC. LINE °F	VAC. MAIN °F	FLOW C.M	H_2O CONDENSED C.C	PH
10:40					PURGED	FROM	24.4	TO 24.8	
10:41	175.0	174.5	24.7	155.5	202	175	7.1	1.7	2
10:52					PURGED	FROM	24.2	TO 24.8	
10:55	175.5	174.5	24.5	155.0	201	178	7.1		
11:07					PURGED	FROM	24.0	TO 24.8	
11:10	175.5	175.0	24.6	155.7	202	180	7.1	.2	2
11:15	CHECK	TORQUE	ON	STUD	BOLTS	50" LBS			
11:22					PURGED	FROM	24.0 TO 24.8		
11:25	175.5	175.0	24.6	155.2	202	182	7.1		
11:37					PURGED	FROM	24.0 TO 24.8		
11:40	175.5	175.0	24.7	155.0	202	182	7.1	.6	2
11:52					PURGED	FROM	24.0 TO 24.8		
11:55	175.2	174.7	24.7	155.0	202	183	7.1		
12:07					PURGED	FROM	24.0	TO 24.8	
12:10	175.0	174.5	24.7	155.0	202	183	7.1	.7	3
12:22					PURGED	FROM	24.1	TO 24.8	
12:25	175.0	174.5	24.7	155.0	202	184	7.4		
12:37					PURGED	FROM	24.0	TO 24.8	
Start 12:40	175.5	175.0	24.7	156.0	203	185	7.4	.8	4
12:52	START	RUN			PURGED	FROM	24.0 TO 24.8		
12:55	175.5	175.0	24.6	155.0	203	185	7.4		
13:07					PURGED	FROM	24.0	TO 24.8	
13:10	175.0	174.5	24.5	156.0	203	186	7.4		
	ICED	COLLECTOR #	TEMP.	4.50° DROPPED OFF					
13:27					PURGED	FROM	24.5	TO 24.8	
13:30	174.0	173.5	24.5	155.2	201	186	7.5		
	TEMP.	CONTROL	TROUBLE						
13:52					PURGE	23.2	TO 24.8		
13:55	175.0	174.5	24.5	155.2	202	187	7.5		
14:08					PURGED	FROM	24.5	TO 24.8	
14:10	172.0	171.0	24.7	155.8	202	187	7.5		

TITLE PERFORMANCE TEST #2
BAROMETER READING 29.15 TEMP COMPENSATED
AN IN-20 MEMBRANE AMF. MEMBRANE #12
ELECTROLITE TEMP. 175°F VAP. PRES. 24.6
FLUID H_2SO_4 CONC - 30%

ENGR. [illegible]
JK
DATE 12-4-62
TEST NO. [illegible]
PROJECT [illegible]

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T_1 H_2SO_4 IN °F	T_2 H_2SO_4 OUT °F	VACUUM PRESS. CM	AIR H_2O °F	VAC LINE °F	VAC LINE MAN. °F	FLOW CM	H_2O CONDENSED CC	PH
14:22					PURGED	FROM	24.5	TO 24.8	
14:25	173.0	172.0	24.7	155.0	202	188	7.5		
14:37					PURGED	FROM	24.0	TO 24.8	
14:40	175.0	174.0	24.5	155.5	202	188	7.5		
14:52					PURGED	FROM	23.9	TO 24.8	
14:55	176.0	175.5	24.6	155.0	200	188	7.7		
15:07					PURGED	FROM	23.9	TO 24.8	
15:10	175.0	174.5	24.7	155.0	201	188	7.9		
15:22							24.2	TO 24.8	
15:25	173.5	172.5	24.7	155.0	202	188	7.5		
15:37					PURGED	FROM	24.1	TO 24.8	
15:40	175.0	174.0	24.6	154.8	201	188	7.5		
End → 15:52					PURGED	FROM	24.0	TO	
15:55	175.5	175.0	24.7	153.0	201	188	7.5		
16:02					PURGED	FROM	24.4	TO 24.8	
16:15									

Shut Down

PH = 4.5 PAPER

Total Quantity From 12:37 = 5.2 Ml.

TITLE PERFORMANCE TEST #2
BAROMETER READING 29.15 TEMP. COMPENSATED
AMAN-60 MEMBRANE AMF MEMBRANE #12
[illegible] ELECTROLYTE TEMP. 175°F VAP. PRESS. 24.6
FLUID H_2SO_4 CONC. 30%

ENGR. TH
JC
DATE 12-4-62
TEST NO. CLIMAT & STR.
PROJECT [illegible]
PAGE 2 OF 2

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T1 H_2SO_4 IN °F	T2 H_2SO_4 OUT °F	VACUM PRES. CM	CIR. H_2O °F	VAC. LINE °F	VAC. LINE MANI °F	FLOW H_2SO_4 C.M		
08:00	PREPARE	TO	SET	CONDITIONS					
09:40	177	176	25.0	165	190	160	8.0		
09:43					RELEASE	&	PURGE	9CC	PH1
10:13	172	171	28.0	140	194	168	8.2		
10:15					RELEASE	&	PURGE	2CC	PH1
11:05					PURGE	FROM	26.0	TO 30.0	
11:08	176	175.5	29.5	140	198	184		9CC	PH2
11:20					PURGE	FROM	27.0	TO 30.0	
11:22	175.5	175.0	29.0	144	200	184		4CC	PH-2
11:35					PURGE	FROM	27.5	TO 30.0	
11:37	174.0	173.5	28.8	141	202	186		4CC	PH-2
11:47					PURGE	FROM	27.5	TO 30.0	
11:50	175.5	174.5	29.0	140.2	204	192		5CC	PH-3
12:07					PURGE	FROM	27.5	TO 29.5	
12:10	175.0	174.5	29.0	140.8	205	200	8.7	5CC	PH-3
* 12:22					PURGE	FROM	27.5	TO 29.5	
12:25	175.5	175.0	29.0	140.0	204	196	8.7	3CC	PH-5
12:37					PURGE	FROM	27.7	TO 29.5	
12:40	176.5	176.0	29.0	140.2	204	196	8.7		
12:52					PURGE	FROM	27.7	TO 29.5	
12:55	174.0	173.5	29.2	140.0	204	196	9.0		
13:07					PURGE	FROM	27.9	TO 29.5	
13:10	174.5	174.0	29.0	140.5	204	198	8.8		
13:22					PURGE	FROM	27.9	TO 29.5	
13:25	175.5	175.0	29.3	139.8	204	198	8.8		
13:37					PURGE	FROM	27.7	TO 29.5	
13:40	176.0	175.5	29.0	140.4	204	198	8.6		
13:52					PURGED	FROM	27.8	TO 29.5	
13:55	175.2	174.5	29.0	140.2	205	200	8.7		
14:07					PURGED	FROM	28.2	TO 29.5	
14:10	175.3	174.7	29.2	139.2	203	200	8.9		

TITLE PERFORMANCE TEST #3

BAROMETER READING 29.27 @ 74°F

Adiad-60 MEMBRANE AMF MEMBRANE #13

ELECTROLYTE TEMP 175°F VAP. PRESS. 29.0 CM

FLUID H_2SO_4 CONC — 70%

ENGR. T.H / J.K

DATE 12-13-6–

TEST NO. OSMATIC STILL

PROJECT

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T1 H_2SO_4 IN °F	T2 H_2SO_4 OUT °F	VACUM PRES. CM.	CIR. H_2O °F	VAC. LINE °F	VAC LINE MAN. °F	FLOW C.M.		
14:22					PURGED	FROM	28.2	TO 29.5	
14:25	175.5	175.0	29.1	140.0	202	200	8.9		
14:37					PURGED	FROM	28.0	TO 29.5	
14:40	176.0	175.5	29.1	140.0	202	200	9.0		
14:52					PURGED	FROM	28.2	TO 29.5	
14:55	174.0	173.5	29.0	140.0	200	196	9.0		
15:07					PURGED	FROM	28.2	TO 29.5	
15:10	174.5	174.0	29.0	140.2	200	196	9.0		
15:22					PURGED	FROM	28.3	TO 29.5	
15:25	175.0	174.5	29.1	140.2	200	196	9.2		
15:37					PURGED	FROM	28.2	TO 29.5	
15:40	175.5	174.5	29.2	139.9	200	196	9.0		
15:52					PURGED	FROM	28.0	TO 29.5	
15:55	174.0	173.0	29.0	140.0	201	196	9.0		
16:07					PURGED	FROM	28.2	TO 29.5	
16:10	174.8	174.2	29.2	140.0	202	198	8.7		
16:22					PURGED	FROM	28.2	TO 29.5	
16:25	175.0	174.5	29.1	140.0	202	198	8.9		
16:27	SHUT	DOWN							
	EXTRACTED		12.2 C.C.						
		PH =	4	PAPER					
		PH =	< 3.8	METER					

TITLE PERFORMANCE TEST #3

BAROMETER READING 29.27 @ 74 °F

ANION-60 MEMBRANE AMF MEMBRANE #13

ELECTROLYTE TEMP. 175 °F VAP. PRESS. 29.0 C.M.

FLUID H_2SO_4 CONC. 30 %

ENGR. TH

JK

DATE 12-12-62

TEST NO. OSMOTIC STILL

PROJECT 512-029724-18

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T. H_2SO_4 IN °F	T. H_2SO_4 OUT °F	VACUM PRES. C.M.	CIR. H_2O °F	VAC. LINE °F	VAC LINE MAN. °F	FLOW C.M		
* 12:05	174.0	172.0	32.5	121.5	206	180	11.3		
12:17					PURGED	FROM	30.5	TO 33.0	
12:20	174.3	174.0	32.6	118.5	206	182	10.6		
12:32					PURGED	FROM	30.6	TO 33.0	
12:35	175.0	174.2	32.3	120.0	206	186	9.6		
12:47					PURGED	FROM	30.4	TO 33.0	
12:50	174.0	173.0	32.3	120.0	206	188	9.4		
13:03					PURGED	FROM	30.3	TO 33.0	
13:05	176.5	175.5	32.5	120	206	190	8.7		
13:12					PURGED	FROM	31.2	TO 33.0	
13:13	SHUT	DOWN	LEAK	IN ACID	PUMP				
	EXTRACTED		4.5 CC						
	PH	5	PAPER						

TITLE PERFORMANCE TEST #4
BAROMETER READING 29.56 @ 72°F
ANION-60 MEMBRANE AMF MEMBRANE #13
ELECTROLYTE TEMP. 175°F VAP PRESS. 32.5
FLUID H_2SO_4 CONC 30%

ENGR.
DATE 12-14-62
TEST NO.
PROJECT

TPFC-557

Thompson Ramo Wooldridge Inc.

TIME	T_1 H_2SO_4 IN °F	T_2 H_2SO_4 OUT °F	VACUM PRES CM	CIR. H_2O °F	VAC. LINE °F	VAC. LINE MAN °F	FLOW C.M.	H_2O CONDENSED CC	P.H
13:40					PURGE	FROM	17.8 To	23.5	
13:43	195.0	193.0	20.0	180.0	206	174	6.5	.4	2
14:07					PURGE	FROM	16.1 To	19.0	
* 14:10	200.0	198.0	16.5	180.0	206	180	6.0	.05	5
14:22					PURGE	FROM	15.4 To	17.0	
14:25	200.0	198.5	15.9	180.4	206	182	5.8		
14:37					PURGE	FROM	14.6 To	17.0	
14:40	199.5	198.0	15.3	180.1	206	186	7.2		
14:52					PURGE	FROM	14.5 To	16.5	
14:55	199.2	198.8	14.7	181.0	208	188	7.6		
15:09					Purged	from	13.9 To	16.0	
15:14	198.8	198.0	14.6	182.0	194	184	8.0		
15:27					Purged	From	14.2 To	16	
15:30	198.0	197.2	14.6	181	250	220	8.0		
			Shut	Down					
							failure in	Vacumm	
							line due to		
	EXTRACTED			20 C.C			over heating		
	PH	4-5	PAPER						

TITLE PERFORMANCE TEST #5

BAROMETER READING 29.11

ANION-60 MEMBRANE AMF MEMBRANE # 13

ELECTROLYTE TEMP. 200°F VAP PRESS. 14.7

FLUID H_2SO_4 CONC 30%

ENGR.

DATE 12-17-62

TEST NO.

PROJECT